



LAWRENCE  
LIVERMORE  
NATIONAL  
LABORATORY

# Enhanced photoluminescence in plasmonic resonant nanocavities

K. Munechika, T. Bond, M. Bora, A. SP. Chang, E. M. Behymer, D. A. Dehlinger, J. A. Britten, C. C. Larson, H. T. Nguyen

November 27, 2012

Materials Research Society  
Boston, MA, United States  
November 25, 2012 through November 30, 2012

## **Disclaimer**

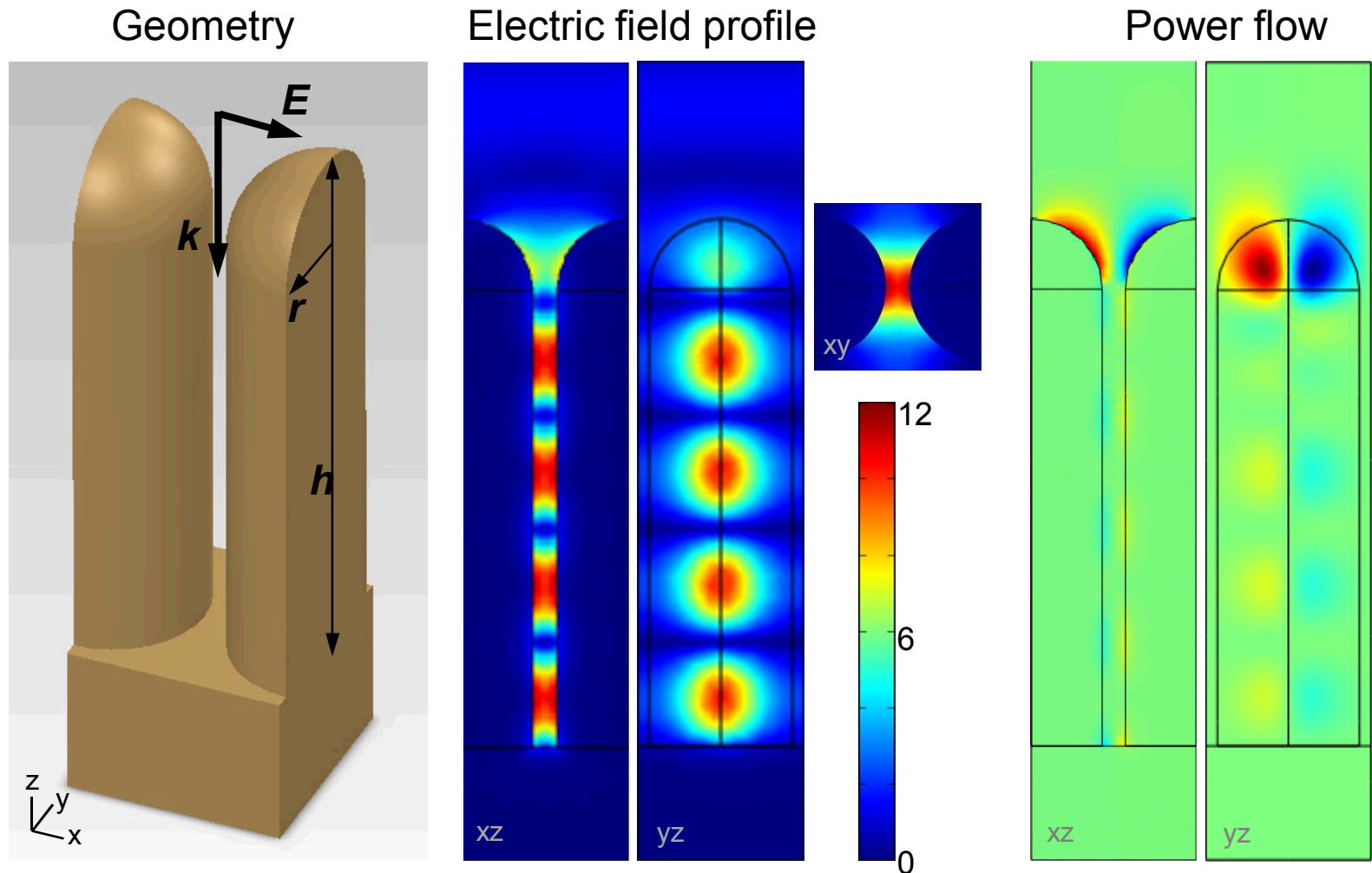
---

This document was prepared as an account of work sponsored by an agency of the United States government. Neither the United States government nor Lawrence Livermore National Security, LLC, nor any of their employees makes any warranty, expressed or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States government or Lawrence Livermore National Security, LLC. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States government or Lawrence Livermore National Security, LLC, and shall not be used for advertising or product endorsement purposes.

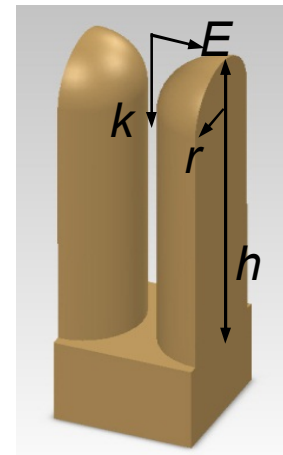
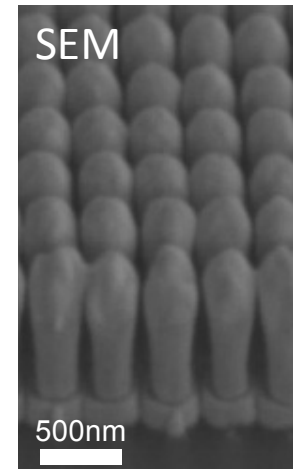
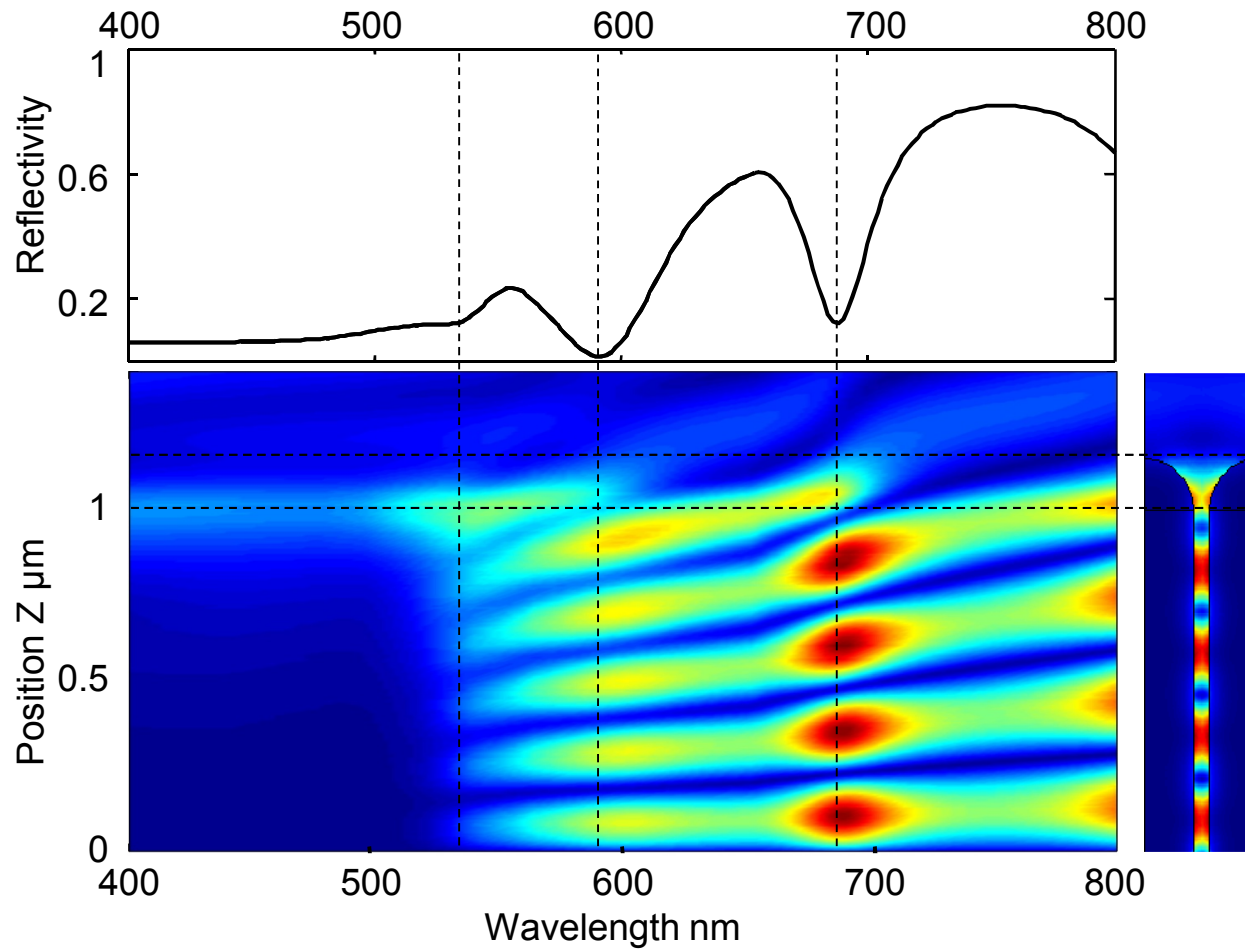
# Enhanced Photoluminescence in Plasmonic Resonant Nanocavities

K. Munechika, M. Bora, E. M. Behymer, D. Dehlinger, J. Britten,  
C. C. Larson, A. SP Chang, H. T. Nguyen, and T. Bond  
Lawrence Livermore National Laboratory

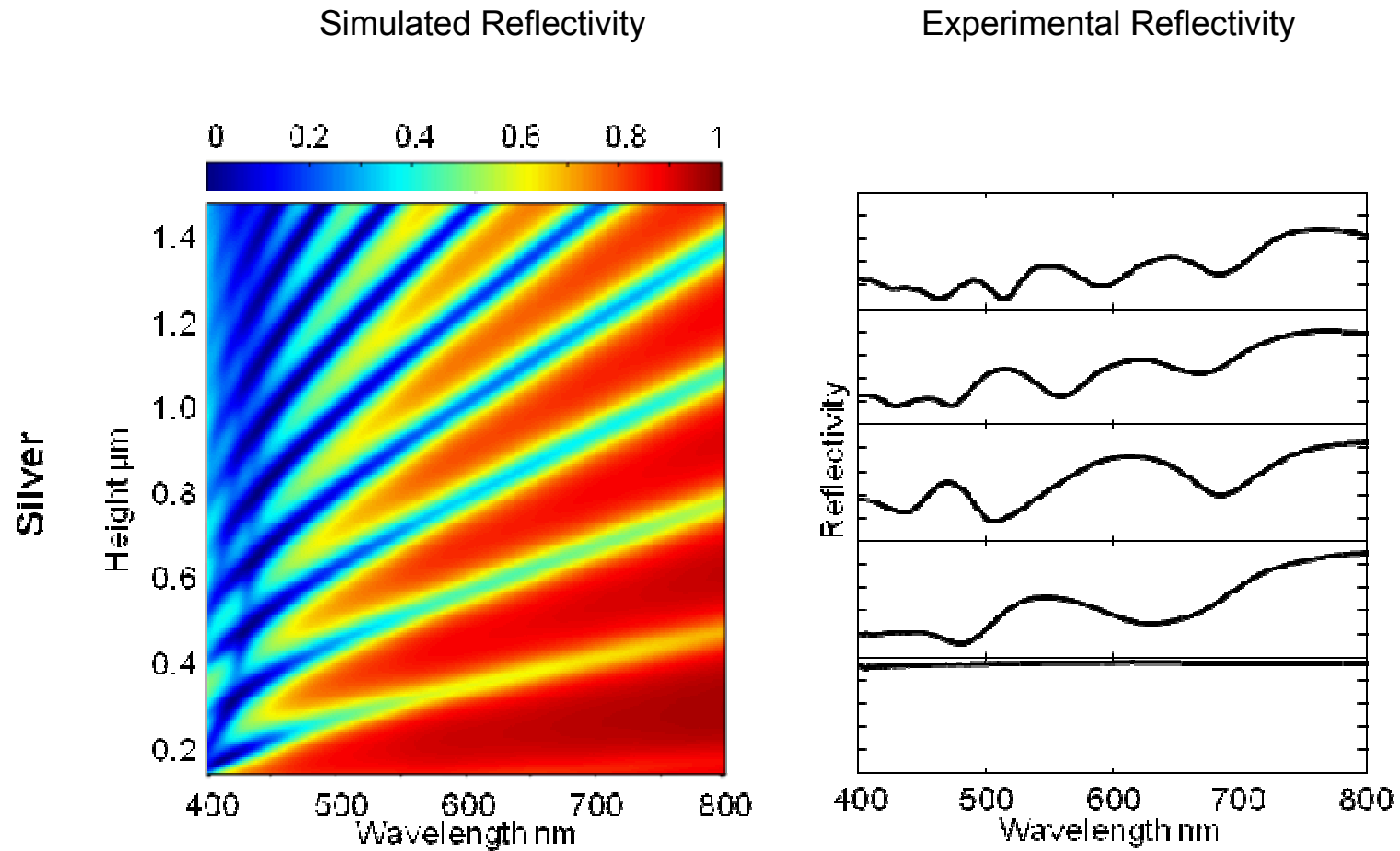
# Plasmon resonant cavities



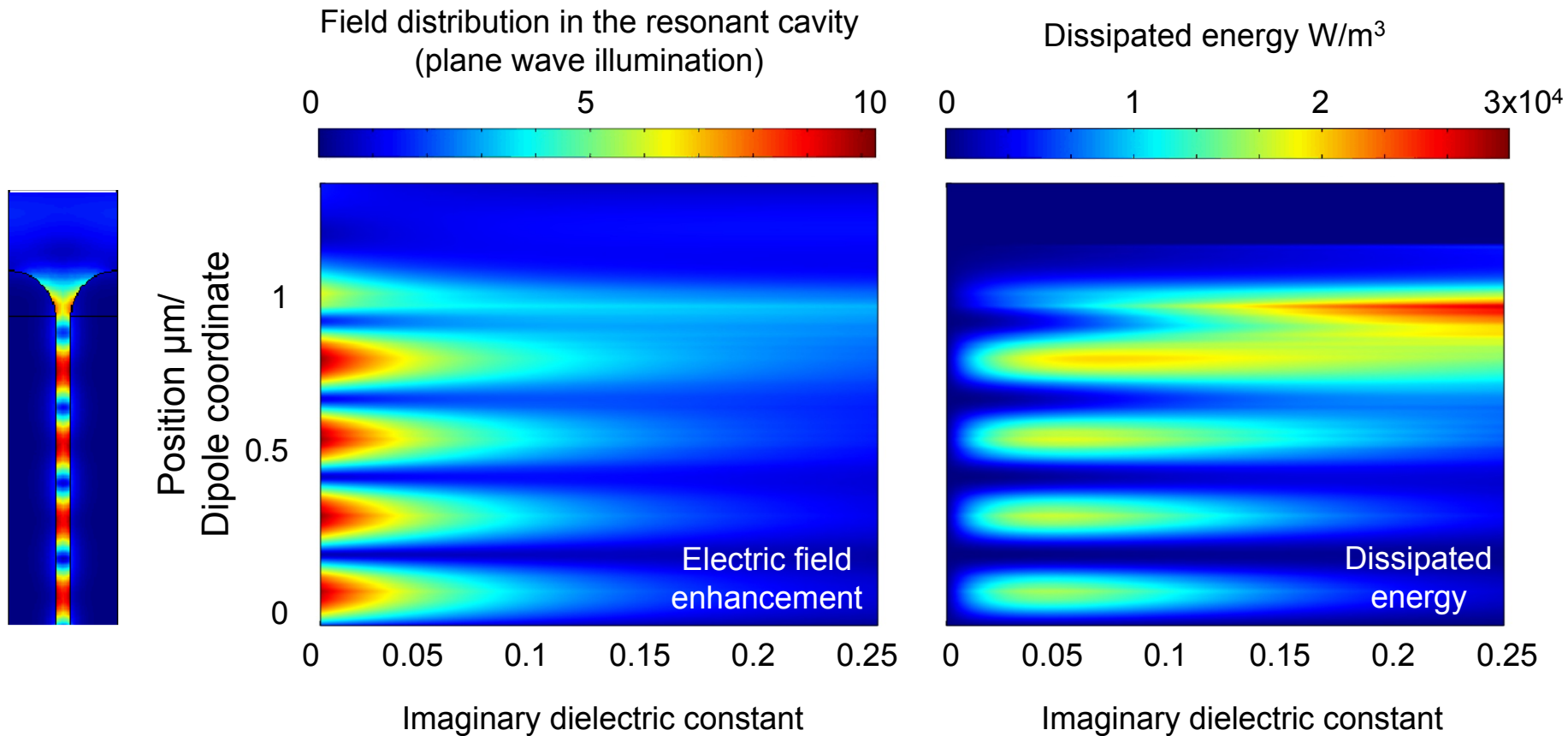
# Plasmon coupling with incident radiation



# Tuning the plasmon resonance



# Enhanced dipole absorbance

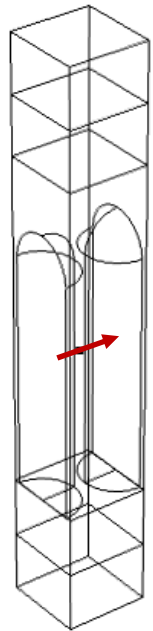


The field enhancement decreases with absorbance

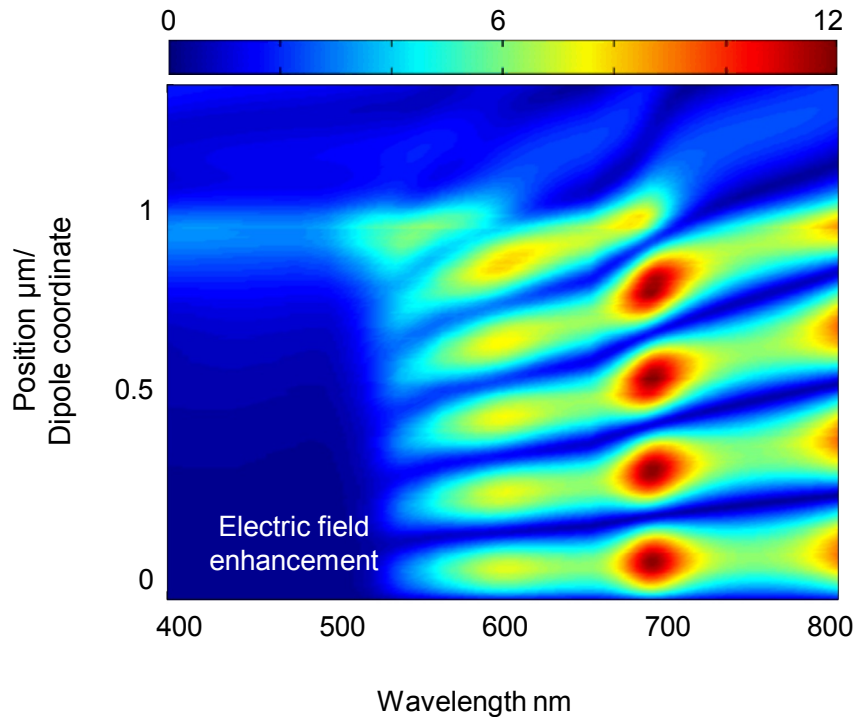
Dissipated energy in the cavity has a maximum with respect to  $\epsilon_{im}$

$$\alpha_{abs} = \frac{2\pi\epsilon_{im}}{\lambda_0}$$

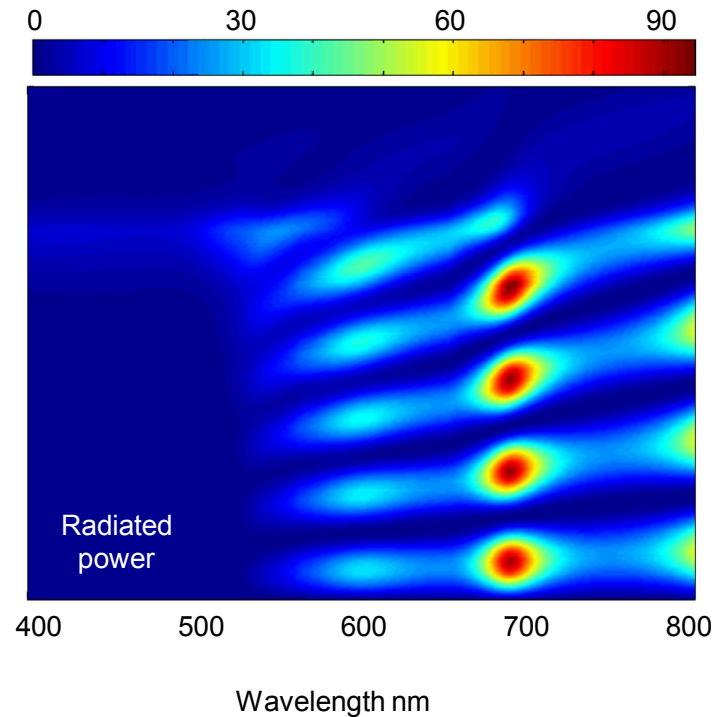
# Enhanced dipole emission



Field distribution in the resonant cavity under plane wave illumination



Point-dipole far-field emitted power  
Normalized to free space emission

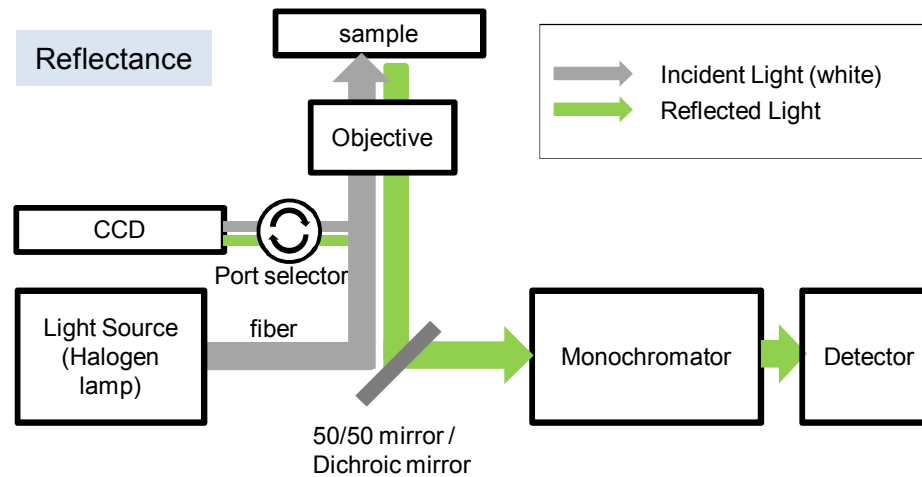


Point dipole emission profile from within the resonant cavity follows the electric field pattern of the resonant modes in both position and frequency

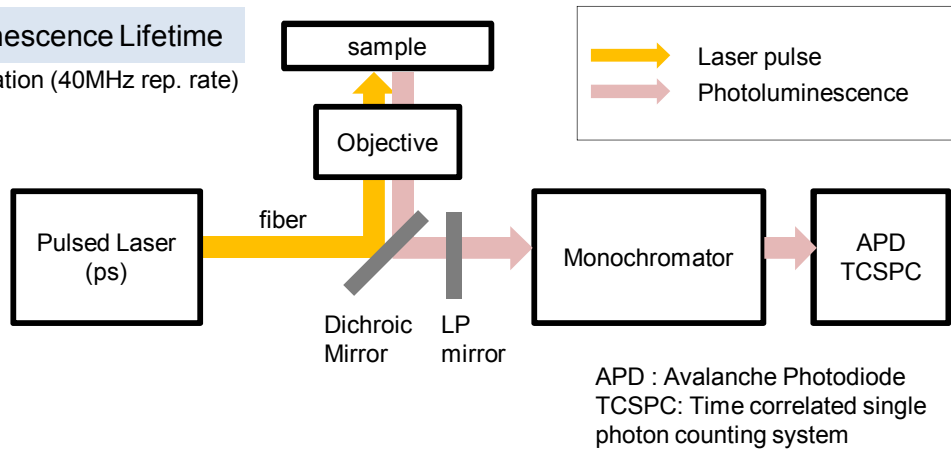
$$\text{Emitted power} \sim E^2$$



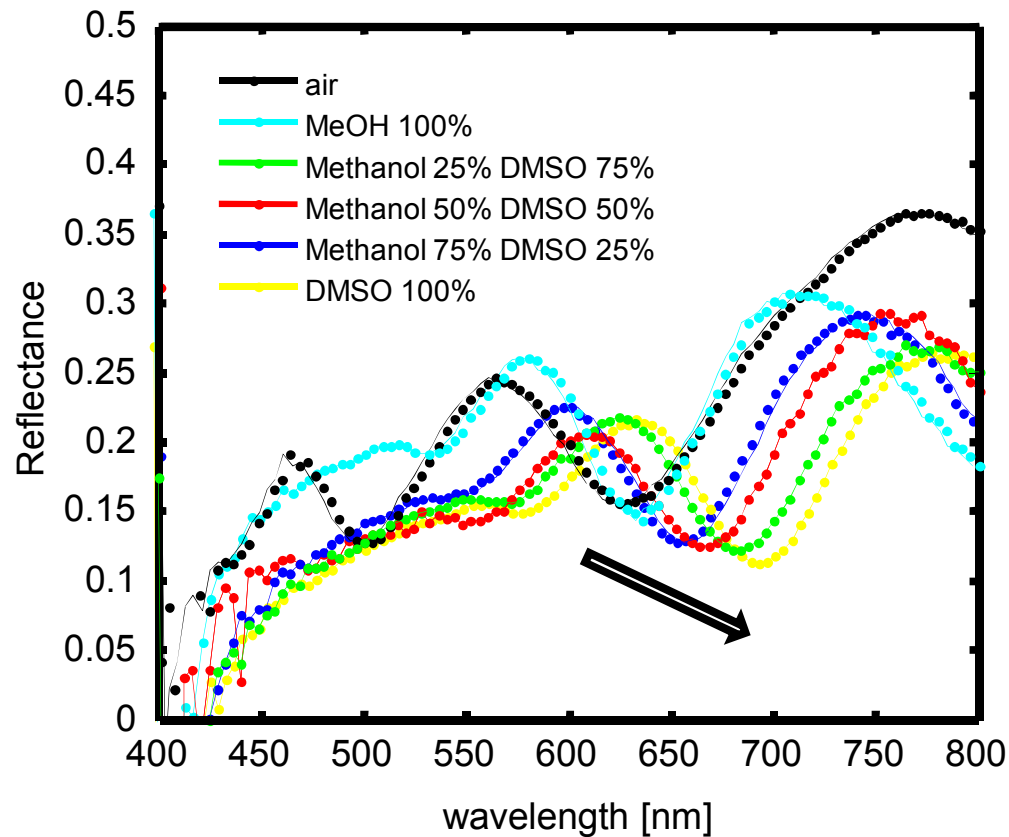
# Experimental Setup



## Photoluminescence Lifetime 632 nm excitation (40MHz rep. rate)

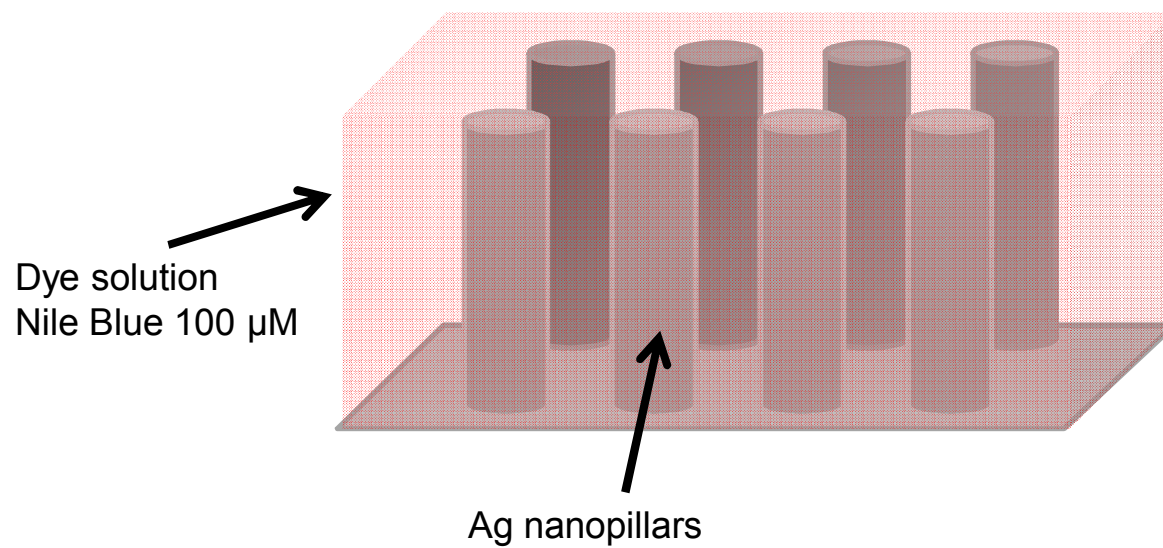


# Tuning the plasmon resonance frequency with solvents

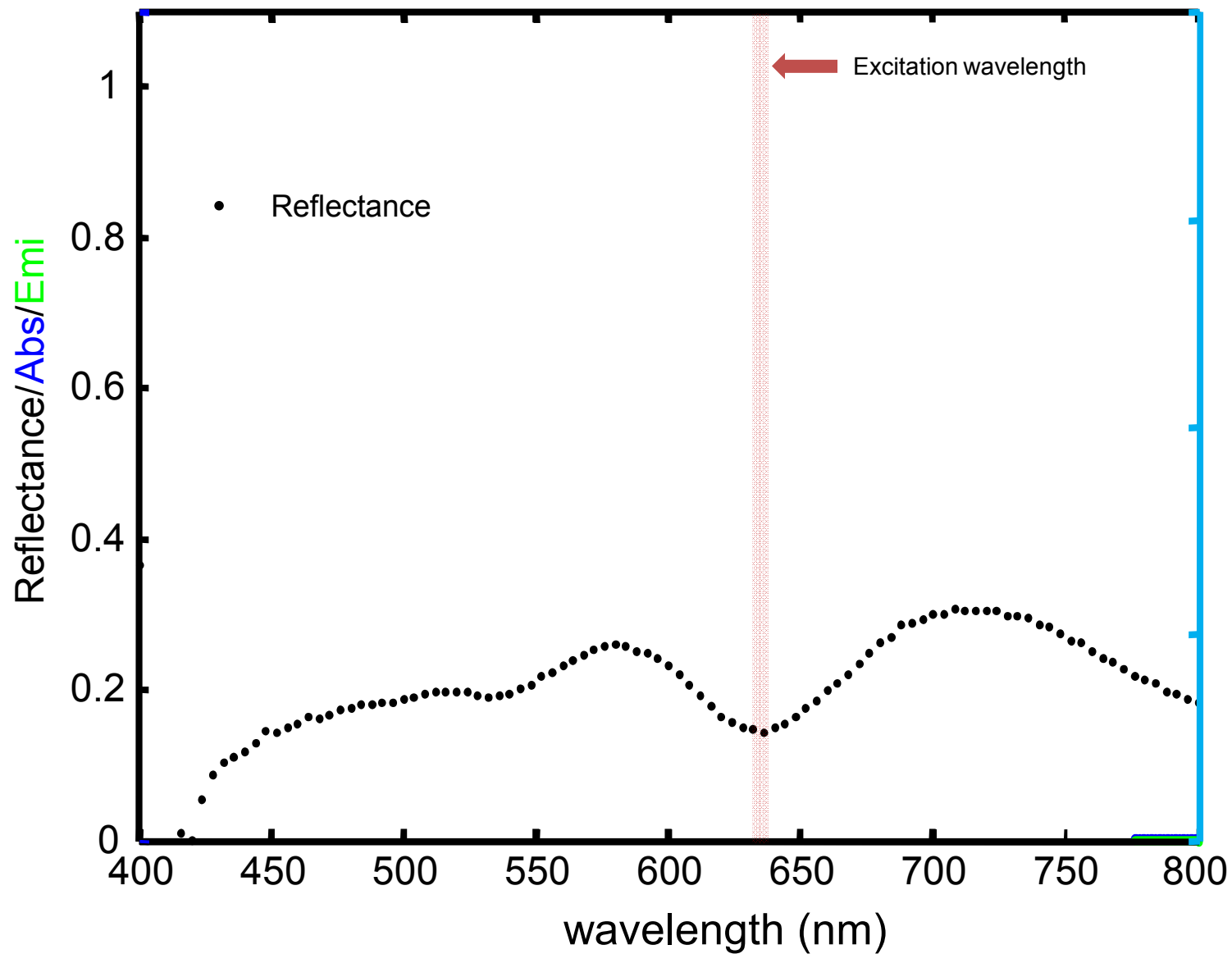


- Reflectance spectra of Ag nanocavities were measured while immersed in solvents with different refractive indices (methanol  $n=1.328$  and DMSO  $n=1.479$ ).

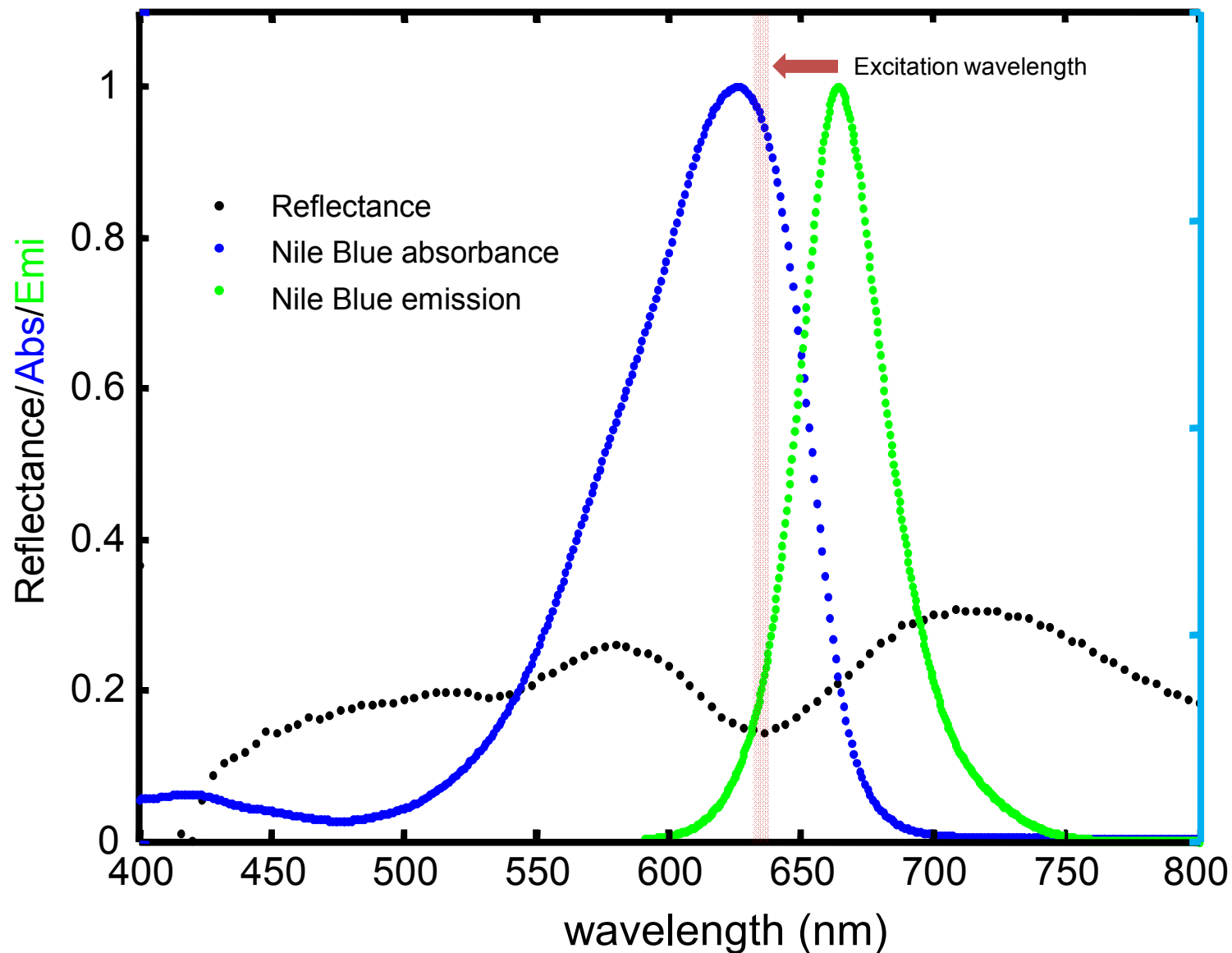
# Sample Scheme



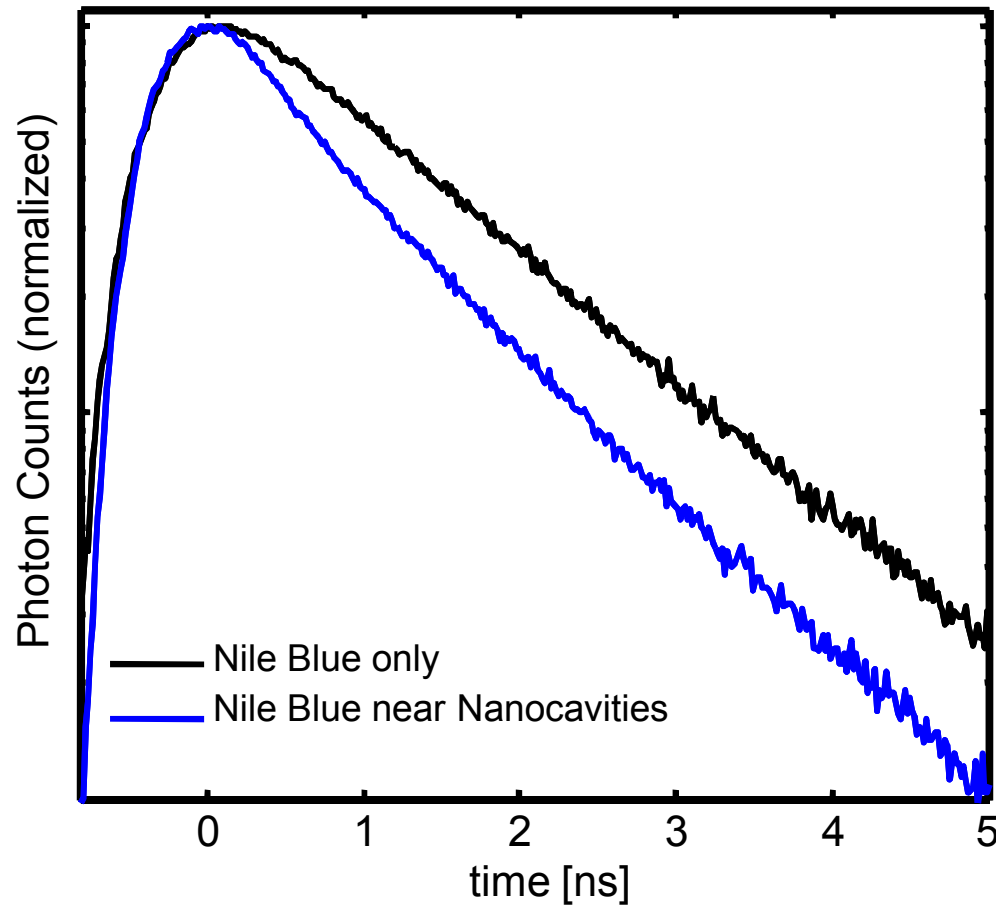
## Correlated PL Lifetime / Reflectance



## Correlated PL Lifetime / Reflectance

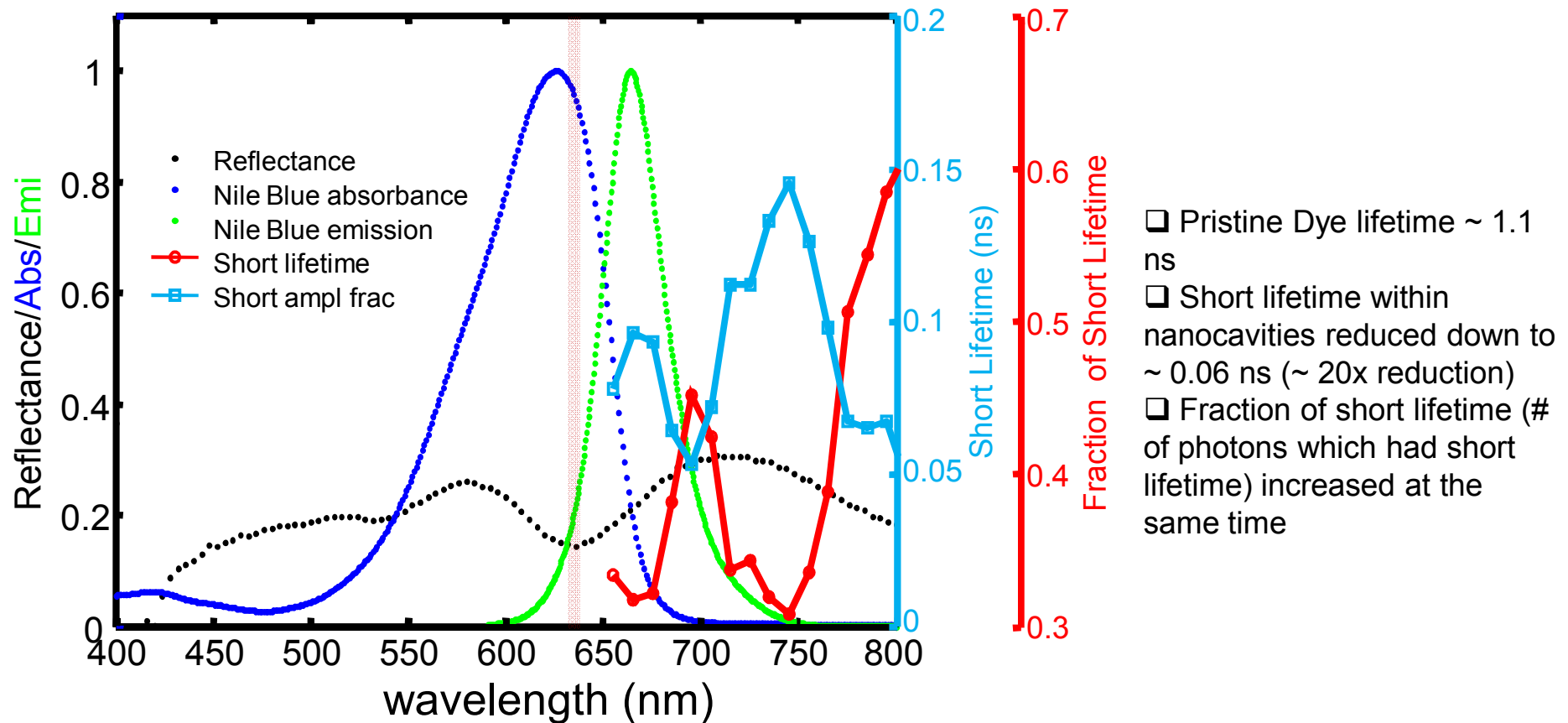


## Correlated PL Lifetime / Reflectance



- ☐ Observed shortening of lifetime from the dyes within nanocavities
- ☐ Lifetime histograms were fitted to double exponential decay
- ☐ Lifetime was examined between 650 -800 nm (10 nm increments)

## Correlated PL Lifetime / Reflectance



## Summary and Future Plans

---

- 3D arrays of nanowires show tunable plasmon resonances in the visible region (height & gap control)
- Plasmon resonance frequency of nanocavities can be tuned ~ 100 nm by changing the RI of solvents
- Observed reduced (~ 20X) photoluminescence lifetime of Nile Blue dyes on the plasmonic nanocavities
- Fraction of shorter lifetimes (compared to pristine dye photoluminescence lifetime) is maximized when the plasmon resonance frequency is off-resonance from the emission maxima
- Future work include parametric study and systematic control of plasmonic resonances with respect to dye excitation/emission frequency



# Acknowledgements

---

Lawrence Livermore National Laboratory  
Engineering Directorate  
Materials Engineering Division

Dr. Ted Lawrence  
Dr. Mihail Bora  
Dr. Sonny Ly  
Dr. Elaine M. Behymer  
Dr. Dietrich A. Dehlinger  
Dr. Jerald A. Britten  
Dr. Cindy C. Larson  
Dr. Allan SP Chang  
Dr. Hoang T. Nguyen  
Dr. Tiziana C. Bond

Thank you for your attention!

Prepared by LLNL under Contract DE-AC52-07NA27344